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Stachybotrys thaxteri sp. nov. and the nomenclatural status of three *Stachybotrys* species

De-Wei Li

The Connecticut Agricultural Experiment Station, Valley Laboratory, 153 Cook Hill Road, Windsor, CT 06095

Correspondence to: *dewei.li@ct.gov*

Abstract — A new species of *Stachybotrys, S. thaxteri*, is described as producing oblong or ellipsoid conidia with a median constriction and undulating diagonal striations and colorless conidiophores up to 360 µm long. The nomenclatural status of *S. cannae*, "*S. pallida,*" and "*S. striatispora*" is clarified.

Key words — anamorphic fungi, *Periconiella*, synonym

Introduction

The genus *Stachybotrys* was erected by Corda (1837: 21) with *S. atra* Corda as type species. Verona & Mazzucchetti (1968), who monographed *Stachybotrys* and *Memnoniella*, accepted 16 species of *Stachybotrys* and 3 species of *Memnoniella*. Jong & Davis (1976) published culture studies of 11 species of *Stachybotrys* and 2 species of *Memnoniella*. Pinruan et al. (2004) accepted 55 taxa in *Stachybotrys* (including seven taxa formerly placed in *Memnoniella*). At present, 96 *Stachybotrys* names have been published (Jiang & Zhang 2009, Wang et al. 2009, Index Fungorum 2010), of which ca. 44 were accepted in the 10th edition of Dictionary of Fungi (Kirk et al. 2008). Since that publication, *Stachybotrys variabilis* H.F. Wang & T.Y. Zhang (Wang et al. 2009) and *Stachybotrys pallescens* Y.L. Jiang & T.Y. Zhang (Jiang & Zhang 2009) have been added.

During study of exsiccati from the U.S. National Fungus Collections (BPI), The Farlow Herbarium (FH), Harvard University, and University of Wisconsin Herbarium, Madison (WIS), one specimen (FH 2633) collected by R. Thaxter labeled as *Stachybotrys* sp. was found to represent an undescribed species, described below as *Stachybotrys thaxteri*. During the same research, *Stachybotrys cannae* (isotype specimen BPI422138) was determined to represent

not *Stachybotrys* but *Periconiella*. The nomenclatural status of *S. cannae*, "*S. pallida*", and "*S. striatispora*" is clarified and those species are redescribed.

Materials & methods

Specimens of *Stachybotrys* on loan from BPI, FH, WIS, and several other herbaria were studied. Fungal structures including hyphae, conidiophores, conidiogenous cells, and conidia were tape-lifted from each specimen with transparent tape (2 × 3 mm) and mounted in lacto-fuchsin (0.1 g acid fuchsin, 100 mL 85% lactic acid). Morphological characters (e.g., conidiophores, conidiogenous cells, conidia) from each specimen were observed with a Nomarski differential interference contrast optical system at three different times (immediately, after one week, after one month) to determine whether rehydration had any effect on the morphology of the fungal structures. Herbarium acronyms follow Holmgren & Holmgren (1998). Articles of the International Code of Botanical Nomenclature are hereafter cited as from the "Vienna Code" (McNeill et al. 2006).

Results

Stachybotrys thaxteri D.W. Li, **anam. sp. nov.** Figures 1–4

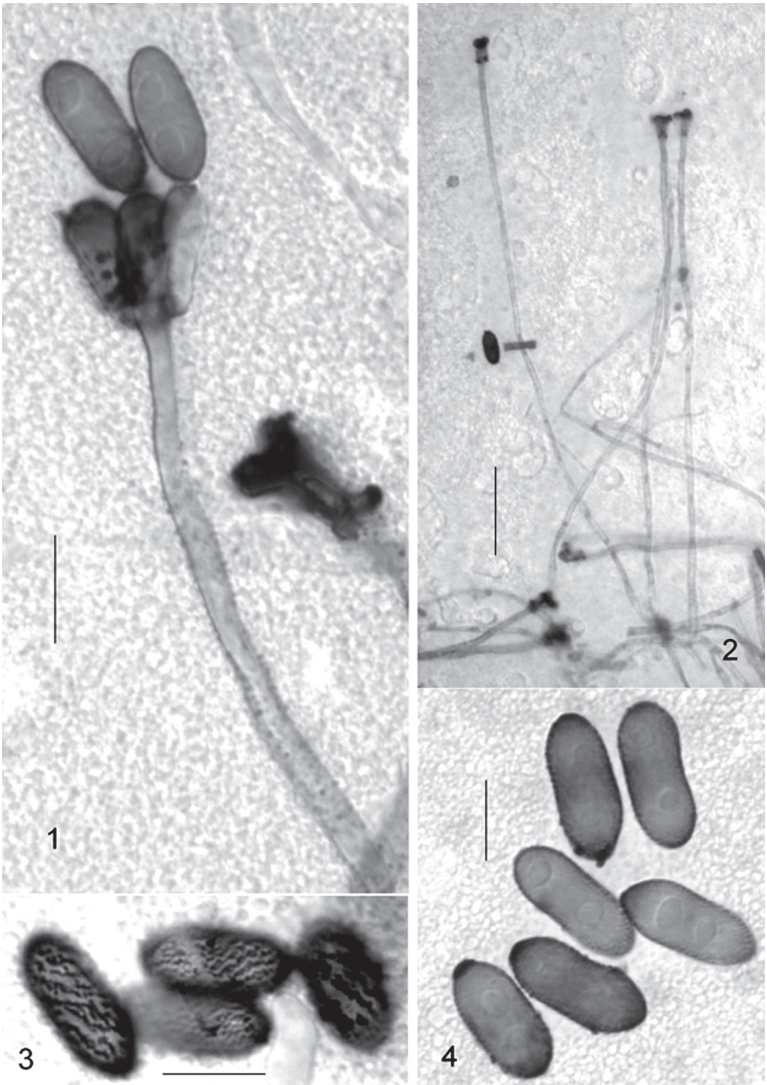
MycoBank MB515398

Coloniae olivascens, effusae, velutinae. Conidiophora macronemata, erecta, simplicia, septata, solitaria vel interdum fasciculata, determinata, recta vel exigua curvata, laevia vel verrucosa, hyalina, usque ad 360 μm *longa et 3.0–5.0* μm *crassa. Cellulae conidiogenae phialidicae, determinatae, discretae, laeviae, subclavatae, prope apicem fuscae olivaceae, (10.5–)11–13(–15.5) × (4.5–)5–6(–6.5)* μm*, collo conspicuo, praeditae, 4–6 in verticillo dispositae. Conidia oblonga, elliptica vel subcylindro-elliptica, primo hyalina et laevia, deinde atro-olivaceobrunnea, diagnaliter striata, (12.5–)15–17.5(–19) × (6–) 6.5–7.5(–8)* μm*, biguttata, in massam mucosam nigram congesta. Teleomorphosis ignota.*

Type: Trinidad: Maravel Valley, de aroid folii, per Roland Thaxter. Coll. 7-XII-1913, FH 2633 (**holotype**).

Etymology: the specific epithet honors Roland Thaxter, the longtime curator of the Farlow Herbarium, Harvard University, who collected the holotype.

Colonies olivaceous, effuse, and velutinous; Mycelia superficial, partially immersed. Hyphae septate, branched, light olivaceous, smooth. Conidiophores differentiated, determinate, solitary or in groups, erect, straight or flexuous, simple, 3–7-septate, smooth to verrucose, hyaline, up to 360 μm in length, 3.0–5.0 μm in width, apices inflated (Figs. 1–2). Phialides , unilocal, determinate, discrete, subclavate, smooth, hyaline, dark olivaceous at the tip, (10.5–)11–13 (–15.5) × (4.5–)5–6(–6.5) μm (mean = 12.2 ± 1.0 × 5.4 ± 0.6 μm, n = 20), with or without conspicuous collarettes, in digitate clusters of 4–6 (Fig. 1). Conidia unicellular, oblong, ellipsoid, occasionally constricted in the middle or slightly curved, rounded at both ends, light gray and smooth at first, gray to dark olivaceous when mature, forming delicate undulating diagonal striations with minute dots in lines on the conidial surface, (12.5–)15–17.5(–19) × (6–)6.5–7.5



Figures 1–4. *Stachybotrys thaxteri*. 1. Conidiophore, phialides, and conidia. 2. Long conidiophores, phialides, and conidium. 3. Conidia showing striations. 4. Biguttulate conidia. Scale bars: 1, 3, 4 = 10 μm, 2 = 40 μm.

(–8) μm (mean = 16.1 ± 1.3 × 7.1 ± 0.4 μm, n = 31), ratio of length/width 1.8–2.7 (mean = 2.3), biguttulate, especially when young, aggregated in slimy masses; the striations becoming thicker and irregular with age (Figs. 3–4, Table 1).

Table 1. Comparative synopsis of *Stachybotrys thaxteri* and similar *Stachybotrys* species.

Species	Conidia				Conidiophores			Type examined
	Size (µm)	Shape	Color	Surface	Size (µm)	Color	Surface	
S. chartarum	7–12 × 3.5–6	broadly ellipsoid	olivaceous	verrucose to ridged	>100 × 2.5–5, variable	brown to olivaceous	smooth, roughened or granulate	Y
S. eucylindrospora	13–16 × 3.5–5.5	cylindrical	olivaceous	striate longitudinally	≤200 × 3–5	colorless to pale olivaceous	verrucose	Y
S. freycinetiae	10–15 × 4–4.5	cylindrical	black	coarsely verrucose	≤320 × 5.5–8.5	colorless or pale brown	smooth or verrucose	Y
S. kampalensis	10–14 × 6–8	oblong	olivaceous	verrucose	150–250 × 8–9	subhyaline to olivaceous	smooth	Y
S. thaxteri	15–18 × 7–7.5	oblong, ellipsoid constricted at middle	olivaceous	striate diagonally	≤360 × 3–5	colorless	smooth to verrucose	Y
S. theobromae	20–28 × 15–18	oval with an apiculus	black	smooth to verrucose	≤200 × 4–6	colorless	smooth	Y
S. variabilis	4–20 × 3–13	subglobse to ellipsoid	pale brown to dark brown	smooth to verrucose	45–70 × 3–4	subhyaline to brown	smooth to verrucose	N
S. virgata	12–13 × 5–5.5	ellipsoid	dark brown	verrucose	100 × 4.5	brown	coarsely verrucose	N
S. xanthosomatis	10–19 × 5–6.5	ellipsoid to cylindrical	olivaceous	coarsely verrucose	120–260 × 3–4	olivaceous	verruculose	N
S. waitakere	15–19 × 8–12	ellipsoid base rounded or with a truncate papilla	black	verrucose	54–75 × 4.5–7	colorless to gray at apex	smooth	N

Teleomorph: unknown.

Distribution and habitat: Known only from Trinidad on aroid leaves.

Additional type specimens of similar *Stachybotrys* species examined: **Canada**. Ontario: Near Guelph, from peat soil, cedar bog, Nov. 1960, G.L. Barron [DAOM 87664, type of *Stachybotrys eucylindrospora*]. **Czech Republic**. Prague, on plaster, A.C.J. Corda [PRM 155670, holotype of *Stachybotrys atra* Corda]. **Germany.** Berlin. Unknown locality, on paper, date, collector unknown [Herb. Inst. Syst. Bot. Uppsala, Sweden. Herb. *E. Fries*, ex holotype of *Stilbospora chartarum* Ehrenb. (≡ *Stachbotrys chartarum*) (DAOM 51026)]. **New Zealand**. Waikato. Mt. Pirongia, No. 3 Track, on *Freycinetia banksii* A.Cunn., 19 Nov 1984, E.H.C. McKenzie [PDD 57639, holotype of *Stachybotrys freycinetiae*]. **Uganda**. Kampala: on dead wood, March 1930, C.G. Hansford (1138) [K(M) 165379, holotype of *Stachybotrys kampalensis* Hansf.]; on dead branches of *Theobroma cacao* L., May 1936, C.G. Hansford (1138), [K(M) 165384, holotype of *Stachybotrys theobromae* Hansf.].

Comments—A comparison of *S. thaxteri* and similar *Stachybotrys* species is given in Table 1.

One striking character of *S. thaxteri* is the long (≤ 360 µm) conidiophore. Both *S. freycinetiae* McKenzie and *S. xanthosomatis* Mercado & J. Mena also have long conidiophores. The holotype of *S. freycinetiae* has conidiophores up to 320 µm long, but its conidia are cylindrical and much smaller (10–15 × 4–4.5 µm; McKenzie 1991) than those of *S. thaxteri*. *Stachybotrys xanthosomatis* produces 120–260 µm long conidiophores and conidia with extremely variable lengths (Mercado & Mena 1988) that overlap those of *S. thaxteri*, but from which it is distinguished by its narrower, ellipsoid or cylindrical conidia (10–19 × 5–6.5 µm). The conidial widths of the two species do not overlap (Table I). *Stachybotrys virgata* has warted conidiophores up to 100 µm long and ellipsoid conidia that are smaller (12–13 × 5–5.5 µm; Krzemieniewska & Badura 1954) than those of *S. thaxteri*. Although the type specimens of *S. xanthosomatis* and *S. virgata* were deposited in herbaria in Cuba and Poland and thus unavailable to the author, the literature descriptions of these two species are detailed enough for comparison.

Conidia of several other species are similar in size or shape to those of *S. thaxteri*. Conidia of *S. waitakere* Whitton et al. are similar in size (14.5–19 × 8–11.5 µm) but differ in ornamentation (verrucose) and shape (ellipsoid to broadly ellipsoid) and are produced on short (≤ 75 µm) conidiophores (Whitton et al. 2001). Conidia of *S. kampalensis* are morphologically similar to those of *S. thaxteri* but smaller (10–14 × 6–8 µm; Jong & Davis 1976; holotype examined). The conidia of *S. theobromae* (20–28 × 15–18 µm; Hansford 1943; holotype examined) and *S. variabilis* (4–20 × 3–13 µm; Wang et al. 2009) overlap those of *S. thaxteri* in size. However, the larger ovoid conidium with the apical apiculus of *S. theobromae* separates that species from *S. thaxteri*.

In *S. variabilis* some conidia are oblong, but smooth to verrucose (not striate) and the size and shape variability combined with the short (45–70 µm)

conidiophores easily separate this species from *S. thaxteri*. Although conidia of *S. thaxteri* and *S. eucylindrospora* are both striate, the longitudinal striations on the smaller (12.8–16 × 3.5–5.5 μm) cylindrical conidia of *S. eucylindrospora* readily distinguish that species from the larger conidia with diagonally oriented striations in *S. thaxteri* (Table 1) (Li 2007).

A culture of *S. thaxteri* was not isolated when the specimen was collected. Therefore DNA sequencing could not be conducted to determine its phylogenetic relationship with the species of *Stachybotrys* that have DNA sequence data in GenBank.

Nomen Excludendum

Stachybotrys cannae Bat.

Examination of this specimen showed that its conidiogenous cells were clearly sympodial and cicatrized, rather than phialidic, and that the fungus had been misdetermined. It is identical with *Periconiella portoricensis,* which is redescribed as follows:

Periconiella portoricensis (F. Stevens & Dalbey) M.B. Ellis, Mycol. Pap. 111: 26 (1967) Figures 5–12

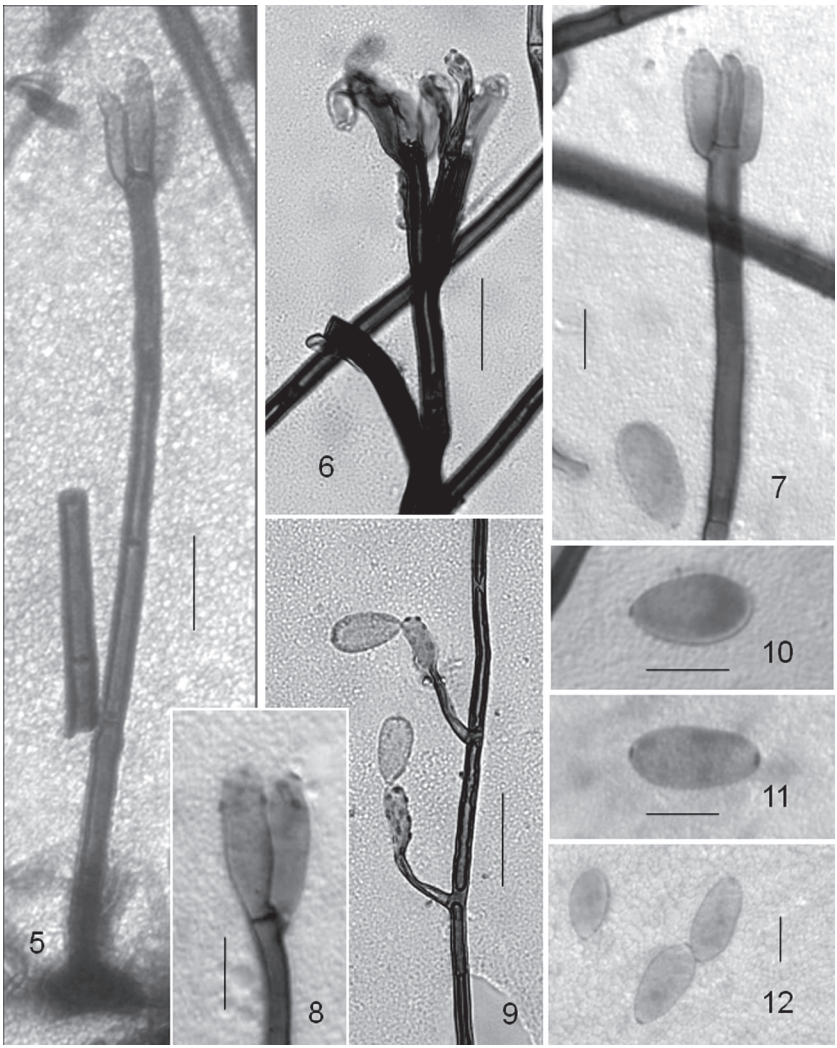
≡ *Haplographium portoricense* F. Stevens & Dalbey, Mycologia 11(1): 6 (1919).

≡ *Cephalotrichum portoricense* (F. Stevens & Dalbey) Toro, Sci. Survey Porto Rico Virgin Islands, New York Acad. Sci. 8: 224 (1932).

= *Stachybotrys cannae* Bat., in Batista & Vital, Anais Soc. Biol. Pernambuco 15(2): 394 (1957).

Colonies brown, velutinous, effuse. Mycelium superficial, partially immersed. Hyphae septate, branched, light brown, smooth. Conidiophores differentiated, solitary or in groups, septate, erect, straight or flexuous, smooth, brown to dark brown, thick-walled, occasionally branched, up to 430 μm in length, 4–6.5 μm in width, with a defined foot cell (Figs. 5–6). Conidiogenous cells clavate or cylindrical, polyblastic, sympodial, cicatrized, smooth, brown, thick-walled in basal area, aggregated in groups of 2 – 5 on the apex of the conidiophores or solitary; solitary ones longer than these in groups; aggregated conidiogenous cells (14–)17–23(–25) × (4.5–)5–7(–8.5) μm (mean = 20.6 ± 3 × 6.1 ± 0.9 μm, n = 20) μm, fertile part as wide as the basal part (Figs. 5–8); solitary conidiogenous cells terminal or intercalary, (19–)23–34(–43.0) × (5–)5.5–7(–7.5) μm (mean = 29.2 ± 5.5 × 6.3 ± 0.8 μm, n = 15) μm, fertile part often wider than the basal part (Figure 9). Conidia unicellular, acropleurogenous, single or in short chains, obovoid, ellipsoid or subcylindrical, brown, smooth or rarely verruculose, (15–)16–20(–22) × (6–)7.5–10(–13) μm (mean = 18.2 ± 1.9 × 9.2 ± 1.5 μm, n = 31) μm, ratio of length/width 1.5–3.2 (mean = 2.0), cicatrized on basal end, occasionally on both ends (Figs. 10–12). Teleomorph unknown.

Teleomorph: unknown.



Figures 5–12. *Periconiella portoricensis*. 5–6, 8. Conidiophores, and conidiogenous cells in groups. 7. Conidiophore, conidiogenous cells in a group, and conidium. 9. Solitary conidiogenous cells and conidia. 10–12. Conidia. Scale bars: 7, 8, 10–12 = 10 μm, 5, 6, 9 = 20 μm.

Distribution and habitat: Known from Ecuador, Guyana and Puerto Rico on *Canna coccinea* Mill. and *Canna* sp.

Specimens examined: **Puerto Rico**. Aibonite: on *Canna coccinea*, 16 July 1915, J. A. Stevenson 8447 [ILL 15999 (= Herbarium of John Stevenson, paratype of *Haplographium portoricense*]; El Giante: on *Canna* sp., 16 July 1915, J.A. Stevenson 8495 [ILL 16000 (=

Herbarium of John Stevenson), holotype of *Haplographium portoricense*]; Guaynabo: on leaves of *Canna* sp., September 1917, J.A. Stevenson 6608 [BPI 422138 (= Herbarium of John Stevenson), isotype of *Stachybotrys cannae*].

Comments—The genus *Periconiella* was erected by Saccardo (Saccardo & Berlese 1885: 727). It is characterized by differentiated conidiophores having a branched head with polyblastic, sympodial, conspicuously cicatrized conidiogenous cells (Ellis 1967). Batista & Vital (1957) proposed *Stachybotrys cannae* as a new species. However, its possession of polyblastic, sympodial conidiogenous cells, rather than phialides, indicates that it should be classified in *Periconiella* rather than in *Stachybotrys*. Unlike *Stachybotrys*, which is defined as having — without exception — unicellular conidia, the conidia of *Periconiella* species are transversely non- to multi-septate (Ellis 1971). Examination of the *Stachybotrys cannae* and *Periconiella portoricensis* type materials led the author to conclude that these two species are conspecific due to their shared conidiogenesis, conidial shape and size, as well as habitat and distribution. Conidia of *S. cannae* were 16–20 × 7.5–10 µm, while those of *P. portoricensis* are 17–20 × 7–10 µm. Since *H. portoricense* (published in 1919) has priority over *S. cannae* (published in 1957), *Periconiella portoricensis* is the correct name of *S. cannae* (Vienna Code Art. 11.4).

Periconiella portoricensis was first described as *Haplographium portoricense*. Toro (1932) transferred this species from *Haplographium* to *Cephalotrichum*. However, this transfer was incorrect, because the species of *Cephalotrichum* have annellidic (percurrently proliferating) conidiogenesis and synnematous conidiophores (Kirk et al. 2008). Ellis (1967) proposed a new combination, transferring *H. portoricense* to *Periconiella*. Because the description and illustrations by Stevens & Dalbey (1919) and Batista & Vital (1957) were not detailed enough to show clearly diagnostic characters such as conidial orientation on conidiogenous loci, photographic illustrations and a detailed description are provided here.

"*Acrodesmis portoricensis* (F. Stevens & Dalbey) M.B. Ellis ined." is listed as an obligate synonym of *Periconiella portoricensis* in Mycobank. Since "ined." refers to an unpublished name, "*Acrodesmis portoricensis*" is nom. inval.

Nomina Invalida

"*Stachybotrys pallida*" Orpurt, Studies on the soil microfungi of Wisconsin prairies. Ph.D. dissertation, University of Wisconsin, pages 95–96 (1954), nom. inval. (Vienna Code, Art. 30.5 and 36.1).

The valid name for this taxon is:

Stachybotrys elegans (Pidopl.) W. Gams, Compendium of Soil Fungi (London): 746 (1980).

≡ *Hyalobotrys elegans* Pidopl., Fungus flora of coarse fodder: 186 (1948).

= *Hyalostachybotrys bisbyi* Sriniv., J. Indian Bot. Soc. 37: 340 (1958).
≡ *Stachybotrys bisbyi* (Sriniv.) G.L. Barron, Mycologia 56: 315 (1964).
= *Hyalostachybotrys sacchari* Sriniv., J. Indian bot. Soc. 37: 341 (1958).
≡ *Stachybotrys sacchari* (Sriniv.) G.L. Barron, Mycologia 56: 315 (1964).
= *Stachybotrys aurantia* G.L. Barron, Can. J. Bot. 40: 258 (1962).

Specimens examined: **Canada**. British Columbia: Vancouver International Airport, Straw from interior of cushings shipped from Thailand and seized at the airport, 13 January 1998, G. White, [DAOM 225565 (labeled as *S. bisbyi*)]. Ontario: from soil, J.A. Traquair, [DAOM 222969]. Ottawa, isolated from serially washed roots of yellow birch, November 1961, E.A. Peterson, [DAOM 87338 (labeled as *S. bisbyi*)]. Ottawa, CEF, from soil, 18 August 1998, D. Overy, [DAOM 226830]. **Egypt**. from soil, 16 December 1965, A.H. Moubasher, [IMI 116426 (labeled as *S. sacchari*)]. **India**. Gwalior, from soil, 15 September 1976, R.K.S. Chauhan, [IMI 206921]. **Kenya**. Nairobi, from *Isoptera* (*Insecta*), 7 November 1985, M.O. Kotengo [IMI 299091]. **Pakistan**. from *Linum usitatissimum* L., 1965, M. Kamal, [IMI 114745 (labeled as *S. sacchari*)]. **South Africa**. from *Saccharum officinarum* L., 19 January 1962, J.R. Anderson, [IMI 91211 (labeled as *S. sacchari*)]. **USA**. Colorado: Fort Collins, isolated from rhizosphere of *Agropyron repens* (L.) P. Beauv., 1969, L.W. Durrell, [DAOM 129721 (labeled as *S. bisbyi*)]. New York: Ithaca, isolated from soil, May 1962, W.J. Jooste, [DAOM 89199 (2 packets) (labeled as *S. bisbyi*)]. Wisconsin: Columbia County, Morrisonville, isolated from soil of Mesic Prairie, on corn meal potato dextrose, 6 August 1952, P.A. Orpurt, [(WIS 55), "holotype" of "*Stachybotrys pallida*"].

Comments— Examination of the type specimen of "*S. pallida*" (WIS 55) revealed only mycelia, with both conidia and phialides lacking. The nomenclatural status of "*S. pallida*" is therefore based on the English description and accompanying illustrations in Orpurt's dissertation. "*Stachybotrys pallida*" (= *S. elegans*) was frequently isolated from the soils of the prairie in Wisconsin (Orpurt & Curtis 1957).

"*Stachybotrys striatispora*" Orpurt, Studies on the soil microfungi of Wisconsin prairies. Ph.D. dissertation, University of Wisconsin, pages 93–94 (1954), nom. inval. (Vienna Code, Art. 30.5 and 36.1).

The valid name for this taxon is:

Stachybotrys eucylindrospora D.W. Li, Mycologia 99(2): 333 (2007).

Specimens examined: **Canada**. Alberta: Waterton National Park, Aspen parkland picnic area, on *Populus* log, 4 August, 1980, G.P. White-696, [DAOM 176800a (2 packets)]. British Columbia: South Burnaby, *Dahlia* stems, 9 August 1957, S.J. Hughes, [DAOM 56386d (2 packets)]. Ontario: near Guelph. From peat soil, cedar bog, Nov. 1960, G.L. Barron, [DAOM 87664, holotype of *Stachybotrys eucylindrospora*]; Ottawa, on stems of "*Ligustrum officinale* Lilach" (invalid pre-Linnaean name), 26 May 1983, W.I. Illman, [DAOM 186941]; St. Lawrence Islands National Park, MacDonald Is. *Carya ovata* husks, 23 July 1979, S.J. Hughes, [DAOM 172376g]. Quebec: MacDonald College, from soil, 1 June 1955, O.A. Olsen, [DAOM 70309 (as *S. atra*)]. **United Kingdom**: England—Yorkshire: Gundale, from *Angelica* sp., 18 October 1959, W.G. Bramley, [IMI 79062 (labeled as *S. atra*)]; Pickering, from *Heracleum* sp., 3 July 1964, W.G. Bramley, [IMI 107222]. **USA**. Wisconsin: Racine County, Mesic Prairie soil (isolated on

corn meal potato dextrose), 23 August 1952, P.A. Orpurt, [(WIS 56 319-13), "holotype" of "*Stachybotrys striatispora*"].

Additional specimens examined: **Israel**. Beeshaba, soil, September 1953, *S. Borat*, [IMI 76515, (labeled as *Stachybotrys atra* var. *cylindrospora* (C.N. Jensen) Rayss & Borut 1958 (= *S. chartarum*), the specimen on which the new combination was based)]. **USA**. New York, North Cohocton, arable soil, August 1911, C.N. Jensen, [CUP 5925, holotype of *Stachybotrys cylindrospora* (= *S. chartarum*)].

Comments—According to Orpurt (1954) "*S. pallida*" was a common species found throughout the prairie in Wisconsin, while "*S. striatispora*" (= *S. eucylindrospora*) was isolated from only two locations. The former species was occasionally isolated from indoor environments.

Although "*S. striatispora*" was proposed much earlier than *S. eucylindrospora*, *S. eucylindrospora* is the valid name for this species due to the nomenclaturally invalid status of "*S. striatispora*". Orpurt (1954) examined a slide prepared by Dr. Richard Korf from the holotype of *Stachybotrys cylindrospora* C.N. Jensen as suggested by Dr. G.R. Bisby. He concluded that *S. cylindrospora* is a synonym of *S. atra* (= *S. chartarum)*. This conclusion is in agreement with the same conclusion drawn by three other authors (Bisby 1943, Gilman 1945, Li 2007).

Discussion

Examination of the specimens from several major herbaria including 31 types has clarified the circumscriptions of the species presented in this paper. In the author's opinion, delineation of several *Stachybotrys* species, such as *S. lunzinensis* Szilvinyi, remains doubtful due to the sketchy descriptions and/or unavailable illustrations and type specimens. Further studies on these doubtful species are needed. Without examining type materials of the species in question or sequencing their DNA (if a culture were available), a nomenclature change would be preliminary and thus add to the confusion.

Stachybotrys cannae may not be the last species transferred to a different genus. One challenge is the availability and accessibility of type materials collected in the 19th and early 20th centuries. A number of types collected at much later times are missing or were destroyed by natural disaster, such as the Kobe earthquake in Japan in 1995 (Matsushima pers. comm. 2008).

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